Phys 131 2016

Lecture 19

Thurs Seminar WS 117

Fri Warm Up 8

Mon: HW by 5pm

Supp 46, ~~81~~ 52

Ch7 CQ 13 Ch8 CQ 4

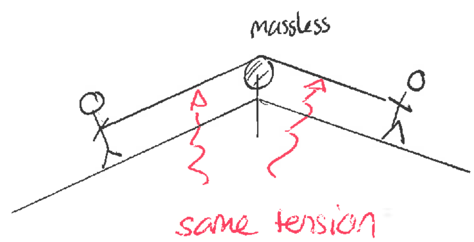
Ch7 Prob 38,40 Ch Prob 6,13

Objects Connected by Massless Ropes

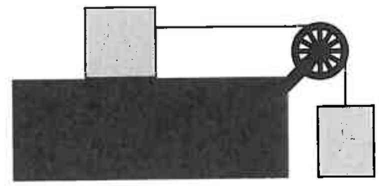
Whenever objects are connected by massless ropes (that run over massless pulleys, etc, ...) the tension at any two points in the rope are the same

Quiz 1 60% → 60% ~ 40% - 70%

Quiz 2 50% - 70% ~ 40% - 90%



48 Dynamics of Connected Objects: Level/Suspended Blocks with Friction



A 6.0 kg crate is suspended from a rope which runs over a massless pulley and is connected to a 4.0 kg box, which can move along a rough horizontal surface. The coefficient of friction between the box and surface is 0.25. The string connected to the box on the surface runs horizontally. The aim of this exercise will be to determine the acceleration of the objects, ignoring any air resistance.

a) Draw a free body diagram for the *box on the surface.*

b) Write Newton's Second Law in component form for the *box on the surface,* i.e. write

$$F_{\text{net } x} = \Sigma F_x = \cdots \tag{15}$$
$$F_{\text{net } y} = \Sigma F_y = \cdots \tag{16}$$

Insert as much information as possible about the components of acceleration at this stage. The resulting equations will generate much of the algebra that follows.

c) List all the components of all the forces for the box on the surface.

$$F_{gx} = \cdots$$
$$F_{gy} = \cdots$$
$$n_x = \cdots$$
$$n_y = \cdots$$
$$\vdots$$

Force	x comp	y comp
$\vec{\mathbf{F}}_g$		
$\vec{\mathbf{n}}$		
$\vdots$		

d) Use Eqs. (15) and (16) and the components to obtain an equation relating the tension in the rope and the acceleration of the box. Can you solve this for acceleration at this stage?

e) Repeat parts a) to d) for the *suspended crate.* Be careful about the acceleration!

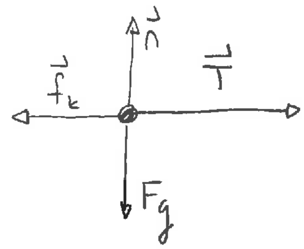
f) Combine the equations for the two objects to obtain the acceleration and the tension in the rope.

The analysis can be performed for objects of any mass. Let m_1 be the mass of the block on the surface, m_2 the mass of the suspended block and μ_k be the coefficient of friction between the block and the surface.

g) Determine an expression for the magnitude of acceleration of the blocks, a. This should be of the form

$$a = \text{formula with only } m_1, m_2, g, \mu_k \text{ and constants.}$$

Answer:

a) 

acceleration $\xrightarrow{\vec{a}}$ $\quad a_x = a$ magnitude of accel.

$a_y = 0$

b) $\sum F_x = ma_x \Rightarrow \sum F_x = 4.0\text{kg}\ a$

$\sum F_y = ma_y \qquad \sum F_y = 0$

c) $F_g = mg = 4.0\text{kg} \times 9.8\text{m/s}^2$

$F_g = 39\text{N}$ (magnitude)

$f_k = \mu_k n$ (magnitude)

	x	y
$\vec{F}_g$	0	-39N
$\vec{n}$	0	n
$\vec{T}$	T	0
$\vec{f}_k$	$-\mu_k n$	0

d) $\sum F_x = 4.0\text{kg}\ a$

$\Rightarrow T - \mu_k n = 4.0\text{kg}\ a$

$\sum F_y = 0$

$\Rightarrow -39\text{N} + n = 0 \Rightarrow n = 39\text{N}$

Thus

$T - \mu_k n = 4.0\text{kg}\ a$

$\Rightarrow T - 0.25 \times 39\text{N} = 4.0\text{kg}\ a$

$\Rightarrow T - 9.8\text{N} = 4.0\text{kg}\ a$

Two unknowns: T, a cannot solve...

e)

$\sum F_x = ma_x = 0$

$\sum F_y = ma_y$

Now acceleration is $\downarrow \vec{a}$

Thus $a_x = 0$
$a_y = -a$ (same magnitude as box)

$\Rightarrow$ $\sum F_x = 0$
$\sum F_y = 6.0\,kg(-a) = -6.0\,kg\,a$

Then $F_g = mg = 6.0\,kg \times 9.8\,m/s^2 = 59\,N$

Thus $\sum F_y = \dots$ $\Rightarrow$ $T - 59\,N = -6.0\,kg\,a$

f) From second $T = 59\,N - 6.0\,kg\,a$

and $T - 9.8\,N = 4.0\,kg\,a$

$\Rightarrow$ $59\,N - 6.0\,kg\,a - 9.8\,N = 4.0\,kg\,a$

$\Rightarrow$ $49\,N = 10\,kg\,a$

$\Rightarrow$ $a = 4.9\,m/s^2$

Then $T = 59\,N - 6.0\,kg\,a$ $\Rightarrow$ $T = 59\,N - 6.0\,kg \times 4.9\,m/s^2$

$\Rightarrow$ $T = 29\,N$

g) For box $\quad \sum F_y = 0 \Rightarrow n = M_{box}\, g$

$$\sum F_x = M_{box}\, a \Rightarrow T - f_k = M_{box}\, a$$

$$\Rightarrow T - \mu_k n = M_{box}\, a$$

$$\Rightarrow T - \mu_k M_{box}\, g = M_{box}\, a$$

For crate $\quad \sum F_y = M_{crate}(-a) \Rightarrow T - M_{crate}\, g = -M_{crate}\, a$

$$\Rightarrow T = M_{crate}\, g - M_{crate}\, a$$

Thus $\quad M_{crate}\, g - M_{crate}\, a - \mu_k M_{box}\, g = M_{box}\, a$

$$\Rightarrow M_{crate}\, g - \mu_k M_{box}\, g = M_{crate}\, a + M_{box}\, a$$

$$\Rightarrow [M_{crate} - \mu_k M_{box}]\, g = [M_{crate} + M_{box}]\, a$$

$$\Rightarrow a = \frac{M_{crate} - \mu_k M_{box}}{M_{crate} + M_{box}}\, g$$

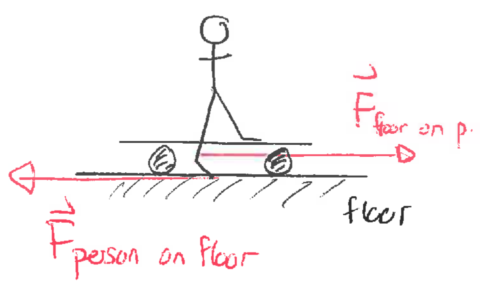
Quiz 3 70%

Quiz 4

Newtons third law explains various ordinary situations

1) "Pushing off" a skateboard

- person's foot exerts a (friction force on floor)



- floor exerts a force on foot with equal magnitude + opposite direction
- $\sum_{\text{person}} \vec{F} = m_{\text{person}} \vec{a}$

floor on person causes acceleration

2) Rocket propulsion

- rocket can function in free space (vacuum)
- rocket pushes gas $\Rightarrow$ rocket exerts force on gas

$\Rightarrow$ gas exerts force on rocket

$\Rightarrow$ rocket accelerates